Photographic Irradiation

As the question of whether irradiation is due to the imperfection of the instruments, or to an action taking place within the thickness of the collodion film, is a matter of considerable importance in all cases in which photography is made use of for the purposes of accurate measurement, I have repeated and somewhat varied the experiments which have lately been described in NATURE, vol. x. pp. 205, 223, by Mr. Ranyard. I therefore laid on a uranium dry plate a piece of platinum foil, and with full aperture of lens took, with an exposure of twenty-five minutes, a photograph of a piece of cardboard, in which were four parallel slits, hung against a background of bright sky. In spite of the long exposure, the images of the slits are sharply cut off at the place occupied by the edge of the platinum foil, though at the same time there are very marked traces of the outer hazy irradiation arising from reflection from the back of the plate. I then took with the same exposure, and under what seemed to be similar conditions of illumination, a photograph of the same cardboard sheet, on an extra-sensitive Liverpool plate, and again found that the images of the slits were sharply cut off. This seems to me to decisively show that the irradiation cannot be due to a spreading within the film, caused by the light dispersed from the highly illuminated particles in the collodion, as suggested by Mr. Aitken; and I feel inclined to agree with Lord Lindsay and Mr. Ranyard that it must be due to some cause that has its seat of action in front of the collodion film.

Bedford W. C. CROFTS

Feathering in Flint Weapons

IT is now some years since I first noticed the fact that in a number of flint weapon heads in my possession a distinct spiral could be traced in the form, this being evidently due in part to the direction of the line of fracture in the flint, but also in part to an exaggeration of this by the hand of the workman. In the last number of the *Scientific American* is depicted an arrow-head with the edges very distinctly feathered, so that if the weapon with which it was armed was propelled with any great rapidity, its revolution would be a matter of necessity and would result in a greater steadiness in its line of trajectory.

After having ascertained that my own weapons were all twisted, I examined a number of others with the view of ascertaining if the same spiral existed in them, and in all I found that there was something like it, and the more finish they presented the more twisted they were.

A very simple method enabled me to show the twist well. I pressed a flint between two pieces of greased pipeclay, then removed it carefully and filled its place with liquid plaster of Paris. Cross-sections of this cast in various directions showed the twist to perfection, and I found that the two wings of the flint were twisted in opposite directions though identical in relation to the axis of rotation), and that the curvatures were identical with those seen in the iron arrow-heads provided with wings which are used in many savage countries to this day, and were till lately, if indeed they are not still, made in large quantities in Birmingham. The most perfectly twisted stone arrow-head which I have yet seen is one made of quartz, where the line of fracture could not help the manufacturer in the least, and where it must have been the result of deliberate workmanship. It was an American weapon. The line of fracture of flint always gives a more or less pronounced spiral, and this may be one of the many reasons for its having been almost universally selected as the material for arrow-heads when it could be got. In fact, it is a difficult thing to find a flint flake of any size which has not a very evident spiral form, and I have a photograph in my possession of two weapons which I have examined and which are almost identical, one found without its shaft near Bridlington, in Yorkshire, and one with its shaft found in the hands of a native of New Zealand; and it would be impossible to tell, from the style of manufacture, which weapon belonged to which country. It is impossible to regard this as mere coincidence, but we must look on it, in each case, as an independent discovery of the principle of the rotation of the rifled projectile. LAWSON TAIT

LOCALISATION OF FUNCTIONS IN THE BRAIN

AT one of the last meetings of the Royal Society, Dr. Burdon-Sanderson related the results of experiments he had recently made with a view to the further investigation of the important discovery of Hitzig and Fritsch, that there are certain spots on the surface of the cerebral hemispheres by the excitation of which the muscles of the opposite side of the body can be thrown into combined action.

It is well known that Dr. Ferrier, of King's College, who has studied the topographical distribution and limitation of these active spots or areas with great minuteness on a considerable variety of animals, has founded upon his experiments a theory that these spots correspond to organs situated at or near the surface of the hemispheres, and that it is the function of these organs to originate combined voluntary movements. Dr. Ferrier has accordingly proposed to call them "motor centres."

As, however, the facts appeared to Dr. Sanderson to be quite as consistent with the view previously entertained by physiologists that the function of co-ordinating voluntary movements is localised lower down in the cerebro-spinal centres, he thought it necessary to ascertain, with reference to some of the most characteristic combined movements produced by stimulation of the surface of the brain, by the interrupted voltaic current (Hitzig and Fritsch), or by induced currents (Ferrier), whether the very same combinations of movements could not be produced after ablation of the grey substance in which the "centres" for their production were supposed to be contained. If it could be shown that after complete removal of the "centres," the effects to the production of which they were supposed to be essential could still be observed, this would go far to prove that the facts had been misinterpreted; and if it could be further shown, not only that the phenomena might present themselves in animals deprived of the centres from which they were supposed to originate, but that they could be produced in such animals by the same methods and under the same circumstances as in normal animals, this would go far to negative the existence of any organs at the surface of the brain to which the term "motor centre" could with any propriety or accuracy be applied.

In accordance with these considerations, Dr. Sanderson planned experiments, in some of which the superficial convolutions containing "centres" were removed, while in others the whole of the anterior part of the left hemisphere as far down as the outer portion of the *corpus striatum* was taken away with the aid of a sharpened spoon. In each case it was found (1) that when after the removal of the cortical grey substance, the cut surface of white substance is excited by induced currents, movements of the opposite side of the body are produced, which are of the same character as those which result from excitation of the natural surface; (2) that the excitability is limited to certain spots, which can be as sharply defined as those demonstrable on the natural surface; and (3) that the relative positions of the active spots on the cut and natural surfaces respectively correspond closely with each other.

Simultaneously with the publication of Dr. Sanderson's communication, a paper appeared in Eckhardt's *Beiträge*, in which an account was given of very similar experiments, of which the results, though incomplete, corresponded, so far as theory went, with those above related. We learn also that Prof. Hermann of Zürich has also made experiments which have led him to reject in the most unequivocal manner the conclusions of Hitzig and Fritsch.

*THE FORM OF COMETS**

II.

LET us see what ideas, what explanations have been suggested by the aspect of these monstrous phenomena, so evidently subject to the influence of the sun.

On examining comets, the first idea which is pre-

* Continued from p. 229.

sented to the mind is that the head of a comet is the seat of an emission of matter which takes place in a direction opposite to the sun; it seems as if the comet fused at one end, and that the matter thus thrown off is arranged into an immense plume, exactly like the smoke which escapes from the chimney of a steamer at full speed. Let us examine this analogy more closely, and suppose, first, the boat to be motionless, with the smoke ascending vertically in a perfectly calm atmosphere. Each puff of this smoke is sent into the air with a certain speed, and the successive sections of the vertical plume thus formed will represent the positions which these puffs will have reached at the same instant. The puffs first emitted will be the highest; the latest ones will be lowest; if then we knew the law of the ascending movement of any puff, we should thus be able to assign the instant at which each section of the vertical plume was shot forth. Meantime, should we set the steamer moving in the motionless air, the place at which each section is emitted will gradually advance; each of these will ascend almost vertically over its place, for the speed of the horizontal movement which the boat communicates to it will be very rapidly exhausted in resisting the motionless air, and at the end of a certain time these puffs will be found dispersed in an inclined plume, presenting a curvature more or less marked. At first, this curvature will assume a vertical direction, *i.e.* the direction of emission.

On the other hand, the successive puffs, in ascending, tend to spread out; the earliest and highest must then become rarefied and disappear from sight. The tail,—no, I should say the plume of smoke thus formed, must become less and less dense, at the same time becoming less and less distinct and gradually getting obliterated.

Does it not seem as if here we had put our finger upon a complete analogy? The comet proceeds on its way like a steamer; it describes round the sun an orbit elongated like the path of a bomb; heated more and more by the solar rays, its matter is expanded and escapes into space, like that of a rocket. Is it not natural that it should send off a plume analogous to that which escapes from the funnel of a machine in motion? If we knew the rate of emission of each puff of cometary vapour, would we not be able to calculate the place which it must occupy in the tail, and even the form of the tail itself? Reciprocally, after having carefully determined the figure of this tail, would we not be able to form some estimate of the rate of the nucleal emission of the comet? Such, very nearly, was Newton's point of view in studying these magnificent phenomena. The comet of 1680, which appeared in the time of Newton, had a tail of 25,000,000 leagues in length; it forcibly impressed this great geometer, and originated in his mind views similar to the analogy which we have just indicated.

But analogy is not always a perfectly trustworthy guide. Here the differences preponderate considerably over the likenesses. We have certainly in the heavens a heated body which in its progress emits vapours like a gigantic steamer; but where is the funnel, where is the atmosphere? And, remember, the atmosphere here plays an important part, for it is its presence which determines the ascent of the puffs of smoke. If these ascend, it is from the same cause as balloons, because they are lighter than air. Take away the air, instead of mounting they will fall. Well, in the sky there is no air; space is void of matter forming a continuous and ponderous medium, layer on layer, until the surface of the sun is reached. Moreover, Laplace has shown that the power of the sun in attracting a ponderable fluid will not extend beyond a very narrow limit. As to the ether of the physicist, it need not engage our attention for an instant, since, by definition, this hypothetical ether is imponderable. We shall not be much astonished that the genius of Newton should have been content with a similar analogy, if we only reflect on all the difficulties which the doctrine of attraction raised in the minds of the eighteenth century, and on the Cartesian prejudices which greeted its first appearance on the Continent. What would have happened if, at the first, the too absolute terms of this doctrine had seemed to be contradicted by the phenomena of the figure of comets? It was then necessary, at any cost, after having incontestably connected the movement of these bodies with the new doctrine, to let it also be seen, even though it was by an analogy somewhat forced, that their figure could be explained in the same manner.

Now that the doctrine of attraction is established on an immovable foundation, our mind is able to detach itself from the purely metaphysical part of the original affirmations, which presented it to us as the single force to which all celestial phenomena ought to be subordinated. But before invoking another force, it is necessary at the very outset to draw from attraction all the consequences applicable to comets; and we shall do so by showing that the force, which seems constantly to tend to unite, to agglomerate scattered material, is, in reality, also quite capable of producing in certain cases the opposite effect, viz., of undoing existing agglomerations.

To proceed in order, let us ask, first, why comets have tails while planets have not. Is it because comets approach closer to the sun and are thus subjected to a very powerful heat? Certainly not; for the planets Venus and Mercury, especially, are constantly closer to the sun than most of the comets at their perihelion, and yet neither Venus nor Mercury has the faintest trace of a tail. Must we attribute the figure of comets to the parabolic nature of their orbits, in virtue of which their distance from the sun varies enormously, while the planets remain always very nearly at the same distance from the centre of our solar system? An illustrious poet, Lamartine, wishing to depict a creator of the earth, indifferent to his creature, has beautifully said—

Et d'un pied dédaigneux la lançant dans l'espace,
Rentra dans son repos.

If the kick had been stronger, the earth would have been sent to describe a cometary orbit round the sun, *i.e.* an elongated ellipse or a parabola, instead of the circle which it now describes; but, for all that, it would not have become a comet, it would have had no tail. Do you know what shape would be the result on this supposition? The imperceptible solar tides of the ocean would be gradually restrained in proportion as the earth increased its distance from the sun, and soon would disappear altogether; our atmosphere would be more and more condensed into layers always spherical and concentric with the earth; our planet would be lost in the depths of infinite space without any other change than a more marked contraction due to the predominating cold of space.

Are comets, then, formed of matter different from that of the planets? No; such an idea cannot be accepted now that spectrum analysis has told us of the existence of sodium, magnesium, and calcium in the sun, hydrogen in the stars, and our ordinary gases even in the most distant nebulæ. Above all, we find the same elements subject to the same mechanical, physical, and chemical laws.

The truth is more simple. If our planets have no tails, it is because they have an enormous mass; if comets have tails, it is because their mass is extremely small, and because the attraction which this mass exercises upon their materials is not sufficient to hold them back and to overcome the external forces which tend to decompose them.

Now have we hit upon a notion which I must dwell upon all the more that it has not hitherto been sufficiently popularised. You have heard of a general law in the world of organised and living beings, called "the struggle for life," the fight or effort which it is necessary to make

in order to live, *i.e.* to resist the external forces which tend to death. Those that have in themselves a sufficient resisting force are developed and found persistent races; the feeble succumb and disappear. The same law reigns in the heavens. A body would subsist eternally by virtue of its internal forces if it were alone; but every neighbouring body becomes for it a dissolving cause by virtue of the attraction which the former exercises on the latter. The strong resist; they are the planets: the weak yield and end by succumbing; they are the comets.

Mechanics will convince us of this. Let us take a comet far away from the sun, leaving out of consideration at first the very weak attraction to which the former is subject; we can do this, for it is then sensibly the same for all its parts. Its solid, liquid, or gaseous materials are under the influence of their mutual attractions and of the feeble heat which they receive from without, freely disposed in regular layers, superposed so as to form a globe spherical like the earth, a globe whose centre will be occupied by the most compact parts and whose surface will be formed of the lightest parts. Whether this globe be at rest or in motion, if things remain thus, the comet will subsist; you will see its bright nucleus surrounded by a less luminous but quite sunny nebulosity, and this same form will indicate to you a body in which the forces which act on all its parts are directed towards the centre. Such is the first form in which we have represented Donati's comet (Fig. 3).

But if the comet comes nearer to the sun, the solar attraction will rapidly modify this state of things. The parts nearest to the sun will be attracted more strongly than the centre, and will have a tendency to separate from it; the difference of the solar attraction on the various parts of the comet will have the effect of elongating that body somewhat in the direction of the radius vector; this is a phenomenon quite like that of the tides. The second sketch (Fig. 4) of the comet of 1858 offers an example of this; but already the eccentricity of the nucleus ought to put us on our guard against any incompleteness in our present reasoning, founded upon the sole consideration of attraction. Nevertheless, you see, the body remains entire; the solar action being very feeble, at that great distance, the attraction of the comet on its exterior strata still preponderates, and the resultant of these various forces at each point is still turned towards the interior; the layers which compose it are everywhere convex externally, and do not show any symptoms of dissolution.

But bring the comet still nearer to the sun; the attraction of that body will no longer be limited to the production of an elongation; you will see the external layers become still more deformed and finally open out so as to let matter escape.

There exists, for every body placed within the sphere of action of our sun, a surface limit beyond which its matter may not pass, under pain of escaping to that body and falling within the domain of the solar action. This surface limit depends on two things—the mass of the body and its distance from the sun. For a planet like the earth, whose mass is so considerable, this surface limit is very distant, and yet, within the still terrestrial region of its satellite, the moon, a child could lift, without much difficulty, a body which would weigh for us 36,000 kilogrammes, so feeble does the attraction of our globe become at that distance of 60 terrestrial radii. A little beyond the lunar orbit, a body would cease to belong to the earth, and would enter the exclusive domain of the sun. But for a comet, this surface limit is much nearer the nucleus, and, moreover, it draws nearer and nearer, in proportion as the comet approaches the sun. One of the most eminent professors of the high education, M. E. Roche, of Montpellier, has submitted this question to analysis, leaving aside accessory circumstances such as the rotatory movement of the body under consideration and the curvature of its trajectory; he has thus been enabled to discover that the surface which so limits a body in the vicinity of the sun presents two singular points in the direction of the radius vector, setting out from which this surface is widened out into conical network, in such a manner that the dissolution of a body the matter of which reaches or passes beyond these boundaries, is effected principally in the vicinity of the points referred to, flying, so to speak, into two pieces, thus obeying at once the attraction of the comet and especially the thenceforth preponderating attraction of the sun.

And it ought not to be objected to this that there is no reason why the matter of a body should tend thus to be separated from its centre and to fill a volume greater and greater, so as to reach or surpass the fatal limit. This tendency exists; it proceeds from the increasing heat which a body that approaches nearer and nearer to the sun experiences, and from the progressive expansion which thence follows in the matter. Certainly if the earth were drawn nearer to the sun, the dilatation of its solid nucleus would be a small matter, but thenceforth the seas would be reduced to vapour and would pass wholly into the atmosphere. In the case of comets, in which the matter presents a much less marked degree of aggregation—doubtless because its original heat, due to the union of the particles which compose it, was not sufficient to bring about all the chemical reactions—the solar heat produces an expansion comparable to that of gases. According to my calculations, this expansion dilates the radius of the concentric zones which we can distinguish so well in the head of Donati's comet, at the rate of 19 metres per second. So long as these zones remain in the interior of the surface-limit, they are not dissolved; but if they should happen to go beyond it, their materials go off at the bidding of the sun's attraction.

Thus all the conditions of instability are found united in comets. Their mass is extremely small, and, consequently, the surface limit is very near the centre of gravity. Their distance from the sun diminishes rapidly in the descending branch of their trajectory; consequently this surface limit becomes more and more contracted. Finally, their enormous volume tends unceasingly to dilate, because of the increasing heat of the sun, and to cause the cometary matter to shoot out beyond this surface limit.

What becomes of this matter after it is set free by the action of the sun? Having escaped from that of the comet, it will none the less preserve the original speed, *i.e.* the speed which the comet itself had at the moment of separation; this speed will scarcely be altered by the feeble attraction of the cometary nucleus, or by the internal movements of which I have spoken, since these are measured by a few metres per second, while the general motion round the sun takes place at the rate of 10, 15, 20 leagues and more per second. The molecules, separated and thenceforward independent, then describe isolated orbits around the sun, differing very little from that of the comet. Those which are found in advance go a little faster and take the lead; those which are behind remain a little in the rear; so that the abandoned materials are divided along the trajectory of the comet in front and in rear of the nucleus. In time these materials are separated considerably from the body from which they emanate, and are more and more disseminated; but considered at the moment of emission, they will form two visible appendages, two sorts of tails opposed and stratified on the orbit of the comet.

We touch here on the decisive point of our research. To take the final step it will be sufficient for us to consider the two figures 6 and 7. The first represents the successive shapes C, C′, C″, which a comet must take, according to the preceding theory, if there were no other force in play than that of attraction. Fig. 7 represents the actual fact, *i.e.* the forms which a comet assumes in

reality according to its progress in its orbit round the sun, S. Evidently there is no resemblance between these two series of figures. Then the preceding theory fails in some point, and as the error will not have been in the part attributed to attraction, it must be found in the assumption that this is the only force. In other words, it is sufficient to compare the effects of attraction with the real facts, to be convinced that there must be another force at work in the cometary phenomena. And as the former would be capable only of disseminating the matter along the orbit, the new force must be capable of driving this same matter in the direction of the radius vector; it must then be opposed to attraction; it must repel and not draw. What may this force be? Ought it not to make itself felt elsewhere than in the gigantic tails of comets? How can the same body, the sun, at once attract and repel matters of the same origin? And how does it come to pass that since it acts so powerfully on the matter of these bodies, this repelling force of the sun does not change the movement of their nuclei which appear to follow so faithfully the laws of solar attraction? This last question will put us on the right track.

And first, do comets follow rigorously, like planets, the laws of attraction? That the law has been firmly esta-

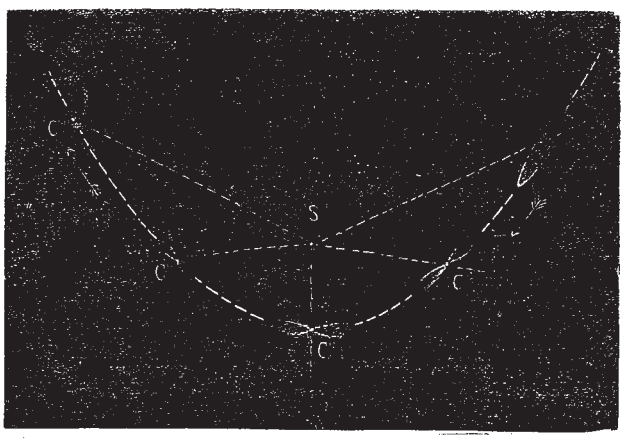

FIG. 6.

blished in the case of the planets, I cannot doubt, for we have for these bodies a historic series of observations going back to the Chaldeans and including thousands of revolutions of each of them. If there had been the least disagreement between the phenomena and the law to which they are assigned, the disagreement, no matter how small, must at length have become sensible, after accumulating during so lengthened a period. But comets, in general, appear only once; we only see them and can only observe them in a very restricted part of their orbit; so that should a very slight influence alter their movements, its effect would be confounded with the inevitable errors of observation, and astronomers would not be able to distinguish it. There are, no doubt, some periodic comets, such as those of Halley, Biéla, Encke, &c., but the first has a period of seventy-five years, so that in going back to its earlier appearances, we very soon reach the time when comets belonged to the domain of astrology. That of Biéla has a period of $6\frac{3}{4}$ years, but its first certain appearance dates only from the end of last century, and in the course of that time a singular accident has happened to it: it has been divided in two. There remains Encke's comet, the only one which can be subjected to the verification of which we have spoken, on account of the numerous revolutions which it has accomplished since its discovery in 1786. Well, it is found that this comet, the only one which can be tested in the way we speak of, does not follow exactly the laws of gravitation. According to these laws, when we have taken account of the perturbations caused by the neighbouring planets, the time of revolution ought to be constant, while, in fact, it diminishes regularly during each revolution; the effect established in this instance is of considerable magnitude, about half a day.

In face of such a fact there is room for the question under consideration, viz., Is attraction the only force which governs the universe? But how can we formulate such a doubt, when the carefully-studied movements of the planets may be perfectly accounted for, for thousands of years past, exclusively by the theory of attraction? We can escape the difficulty by an artifice identical with that which enabled Newton to account for the tails of comets by attraction alone: I refer to that vast and rare atmosphere which Newton placed in space around the sun, and in the midst of which the cometary materials are elevated, according to him, exactly as the smoke of our chimneys in our terrestrial atmosphere. Geometers, then, introduced the resistance which this general medium ought to oppose to the progress of a comet on account of its small density, while the same medium would oppose only an insensible resistance to the planets

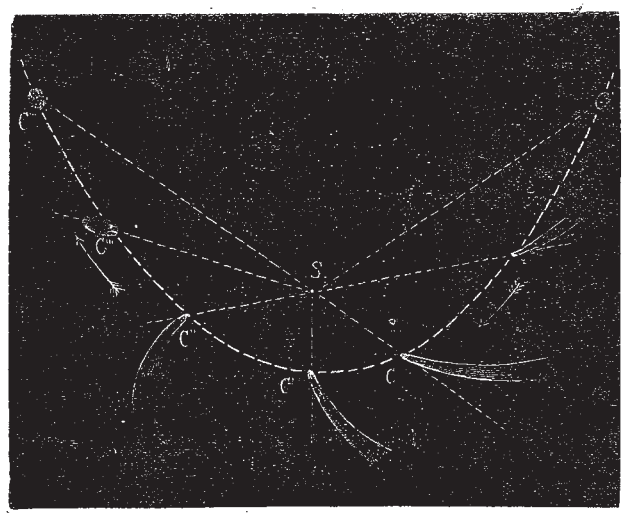

FIG. 7.

on account of their relatively small volume and their enormous density. It is a remarkable fact that the analysis founded on this impossible hypothesis perfectly accounts for the anomaly proved to exist in the orbit of Encke's comet, viz., its progressive acceleration. I feel bound to question this analysis, and to show (1) that its primary basis is radically false, since it leads to the admission that a material and ponderable medium may remain immovable around the sun; (2) that the conclusion of this analysis, so far as it is valid and conformable to observation, simply proves that there must exist an action opposed to the movement of the comet and directed along the tangent to its orbit. Various causes, moreover, may lead to the same conclusion, and differ only, as to other effects, in quantities difficult to appreciate. But we learned above, from the phenomena of the tails, that there also exists an action in the direction of the radius vector. The resisting medium of Encke, or the immense solar atmosphere of Newton, being physically impossible, I have been led, by two different ways, to a new force which would satisfy these data by producing the two actions or components above mentioned: that which expels the cometary molecules in the direction of the radius vector, and that which acts upon the comet in the inverse ratio of its tangential velocity.

(*To be continued.*)